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International Council for the Exploration of the Sea

C.M. 1980/ F: 5
Mariculture Committee

ON THE OXYGEN BALANCE OF AN EXPERIMENTAL EEL FARM [1)] OPERATED IN THERMAL EFFLUENTS OF A CONVENTIONAL POWER STATION

by

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1. Abstract

In an experimental eel farm near the Emden harbour eel-fingerlings were fed in circular fibreglass tanks of 6 to 8 m in diameter and 1.2 m deep. Water level was about 40 cm.

At the theoretical water exchange rate of once per hour an oxygen consumption caused by loss of food and faeces could mainly by the oxygen consumption of the eels.

The oxygen consumption of unfed eels increases expontentially with increasing water temperature. The oxygen consumption of fed eels is about twice as high as that of unfed eels. Normal oxygen consumption is reached - depending from water temperature- within 6-13 hours after feeding.

By adding supersaturated water to the normal inflow the higher demand of oxygen after feeding can be equalized, and by this the oxygen content of the basin water kept constant.

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1) This paper has been submitted also to the EIFAC-Symposium on new developments in the utilization of heated effluents and of recirculation systems for intensive aquaculture held from 28 May to 30 May 1980 in Stavanger.

2. INTRODUCTION

With financial support by the Federal Ministry for Research and Technology the Institute for Coastal and Inland Fisheries of the Federal Fisheries Research Centre carries out fish farming experiments in Emden, using heated brackish cooling water from a conventional power plant. After the examination of some fish species, like Sea bass and Tilapia in the last years, the experiments concentrated on the eel as a high priced fish on the European market. Further details on the Emden experimental station are given by Kuhlmann (1979).

3. MATERIAL AND METHODS

The experimental tanks are directly supplied with the cooling water of the Emden power plant. Temperature and salinity of this are fluctuating depending on season and rainfall as shown in Fig. 1.
The eels are kept in circular tanks of 6 to 8 m in diameter in an open system. 1978 stocking densities are varied from 6.6 to 11.8 kg/m^2, which means 330 to 594 kg per basin of 8 m Ø. 1979 stocking density was increased to 8.2 - 17.3 kg/m^2 (411-865 kg per 8 m-basin). Water level was kept at ~ 40 cm, water exchange was about once per hour in 1978 and two times per hour in 1979.

The eels were fed with industrial food and later with an experimental diet (Koops and Kuhlmann, 1980) at a rate of 1.7 to 0.3 % of the body weight (dry substance), depending on water temperature. The feed conversion was between 1.6 and 2.2.

Experiments on the actual oxygen balance in the tanks were carried out in the time from July to December 1978. In addition in October 1979 experiments with supersaturated water started. Supersaturation was achieved by an oxygenator, [1] operated in a by-pass system, using pure oxygen.
Oxygen and temperature of the water was registrated continuously with a multichannel oxygen measurement system (Orbisphere Mod. 2710) combined with a printer. To avoid faults caused by shifting, the sonde was calibrated by the mean of two Winkler analyses once a day. The differences between

[1] experimental model from Linde AG

Orbisphere values and the Winkler values never exceeded $\pm$ 0.07 mg O_2/l.

The oxygen consumption of the stocked eels was calculated by the formula:

$$O_{2_C} = \frac{(O_{2_1} - O_{2_o}) \times F}{W} \quad (mg/kg/h)$$

where O_{2_C} = oxygen consumption (mg per kg eel and hour)

O_{2_1} = oxygen content of the inflowing water (mg/l)

O_{2_o} = oxygen content of the outflowing water (mg/l)

F = flowrate (l/h)

W = weight of stock (kg)

Measurements have shown that the oxygen content decreases from the periphery to the central outlet of the circular tank, so that the outflowing water has the lowest oxygen saturation. Several experiments have shown that the amount of oxygen consumed by feedlosses and faeces is neglectable in comparison to that of the eels themselves. The rate of reoxygenation of small ponds by atmospheric oxygen amounts to 1,5 g O_2 m^2/d (Knösche, 1971). That means, that in the case of our Emden basins the oxygen input is below 2 % of the whole oxygen input by the inflowing water.

Under favourable conditions (low saturation and low temperatures) the oxygenation due to the turbulence caused by the inflowing water may be measurable. Under the Emden conditions with high temperatures and high oxygen saturation (60 - 80 %), and short time of contact between air bubbles and water due to the low water level (o,4 m) the oxygen input can be neglected.
Even air blowers put into the basin were not able to raise the oxygen content measurable.

So the difference in the oxygen content of the inflowing and outflowing water can be taken as to be caused almost only by the oxygen consumption of the eels.

4. RESULTS

4.1. Oxygen balance in the tanks without aeration

During the time of the experiments the absolute oxygen concentration of the inflowing water fluctuated, depending on water temperature and salinity between 6.6 to 8.9 mg O_2/l. This means that saturation was between 92 and 100 %. Temperature and salinity of the inflowing water for the year 1978 are given in Fig. 1.

After feeding the oxygen content of the basin water decreases and reaches a minimum within about one hour, and then increases again over a period of several hours to reach the former value. In summertime when water temperature is about 27-29^{o}C, at a feeding rate of 1.6 % this time amounts to about 12 h. In winter with reduced water temperatures and a feeding rate of 0.3 to 0.8 % the time of oxygen recovery is reduced to about six hours, as can be seen in Fig. 2.

The oxygen consumption rate of the fed eels is about twice as high as that of the unfed eels. In the summer it is more than twice as high in comparison to the winter values according to the temperature. To prevent critical oxygen situations water influx must be high enough even to satisfy peak oxygen demands of short duration.

According to Itazawa (1971) the minimum oxygen content required for "normal life of fish" is about 2 ml/l (16 - 17^{o}C) for eels in cultivation.

Own experiences have shown, that an oxygen content of 2 mg/l caused a considerable reduction of the feeding activity of the eels and induces them to migrate to the water-inlet of the tank. At an oxygen content below 1.5 mg/l the eels came up to the water surface and started "air breathing".

The Fig. 3 shows the maximum oxygen consumption of eels after feeding plotted against water temperatures. To prevent growth-depression of the eels caused by lack of oxygen, in our Emden station the flowrate normally was adjusted to the weight of the stock in that way, that the oxygen-content of the outflowing water was not less than 4 mg/l.

4.2. Oxygen balance in the tanks with artificial oxygenation

If the quantity of water pumped is adjusted to the maximum oxygen consumption of the eels, most time of the day a lot of surplus water is wasted. To adjust the supply to the actual oxygen demand of the eels, there are two alternatives:

First, to pump additional water during several hours after feeding and second, to use artificial aeration during this time. Normal air-blowers are more or less uneffective, because water depth is only $\sim$40 cm. Only in cases of oxygen contents of 1 - 2 mg/l there might be some effects. So air-blowers can be considered as a kind of "emergency-aeration" for a relatively short time.

Oxygenation has prooved to be much more effective. Application of oxygen during feeding-time shows that the decrease of the oxygen content in the basin could be reduced considerably or even equalized.

Fig. 4 shows the influence of the oxygenation on the oxygen content of the inflowing and outflowing water respectively. The intensity of oxygenation was kept constant. Contrary to all other experiments the water inlet was situated on the bottom of the basin to prevent oxygen losses of the supersaturated water due to turbulance. However, in comparison to other experiments, where the inlet was situated above the surface, in this experiment a negative effect could be observed. Obviously due to a worse water distribution on the bottom, caused by the eels crowding around the inlet, lost food and faeces where not washed out sufficiently and consumed additional oxygen.

Comparing the oxygen contents of the outflowing water with and without oxygenation, as shown in Fig. 4, it can be seen, that by oxygenation the oxygen content can be raised for $\sim$2 mg/l and by this unfavourable levels of $<$ 4 mg/l could be avoided in this experiment. The additional oxygen input was started one hour before feeding and calculated by the increment of the oxygen content of the outflowing water and the flow-rate. The real water exchange rate was about 4 hours. Thus the real capacity of the oxygenator could be prooved not earlier than after 4 hours, i.e. 3 hours after feeding.

Operation datas of the oxygenator in the experiment in Fig. 4 are given in the following list:

pressure	:	0,5 bar
gas input	:	80 l/h
water flow rate	:	1 l/s
O_2	:	17.5 mg/l
capacity	:	63 g O_2/h
efficiency of gas input	:	60 %

In the following experiment the main inlet was situated above the surface. The oxygenated water was given directly into the whirl of this main inlet and the oxygenator started oxygenation at the moment of feeding. Fig. 5 gives the curves of the oxygen content of the inflowing and outflowing water with oxygenation and the expected oxygen content of the outlet without oxygenation calculated from the data of Fig. 2.

During feeding time the gas input was reduced in 3 steps from 250 to 100 and 75 l/h O_2. This allowed to keep a relatively constant level of 5-6 mg O_2/l in the outflowing water.

5. CONCLUSIONS

Besides a lot of other difficulties, often the utilization of warmwater resources is restricted by quality criteria and in many cases - except power-plants and big industries - by limited quantities available. Even in this case of unlimited warm water quantities, the flow-rate can not be increased to

excess, because this would disturb the normal behaviour of the fishes and consequently cause growth-depression and deteriorate feed conversion. One way to overcome these difficulties is to recirculate the whole quantity of the water or at least part of it. Commercially operated systems of this design are not yet known. The other way is to add oxygen to the water, because normally it is the oxygen supply that is restricted by limited water quantities, and not the capacity of the water-flow to wash out metabolites. Thus, by artificially raising the oxygen level of the water not only the stocking density per flow-unit can be increased, but also the growth of the fishes (Huisman, 1976) and by this the productivity of fish farms can be improved.
Further experiments in the Emden experimental station will show, whether increased constant oxygen levels will not only allow higher stocking densities and accelerated growth, but also improve feed conversion, disease-problems and mortality.

6. REFERENCES

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Koops, H. und Kuhlmann, H., 1980	: Annual variation of feeding and growth rate of eels farmed in thermal effluents of a conventional power station. EIFAC/80/Symp.: E/3, 28-30 May 1980
Knösche, R., 1971	: Möglichkeiten zur Belüftung von Wasser in Fischzuchtbetrieben. Z. Binnenfischerei DDR, 18: 331-340
Kuhlmann, H., 1979	: Fish farming experiments in brackish thermal effluents of a power plant. Advances in Aquaculture, Fishing New Books Ltd., FAO Techn. Conf. on Aquaculture: 502-505

Fig. 1: Annual water temperature and salinity of the inflowing water in 1978, Emden

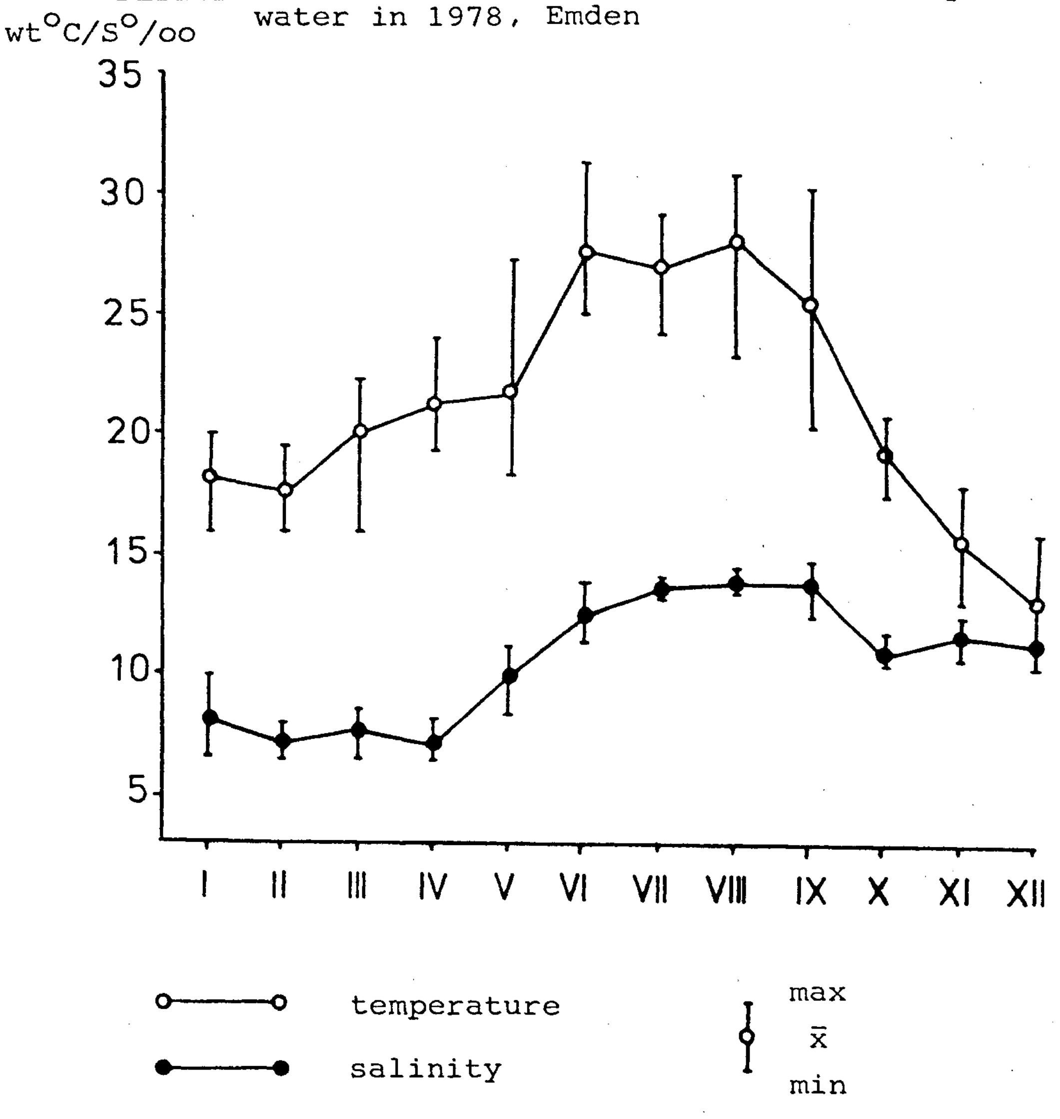
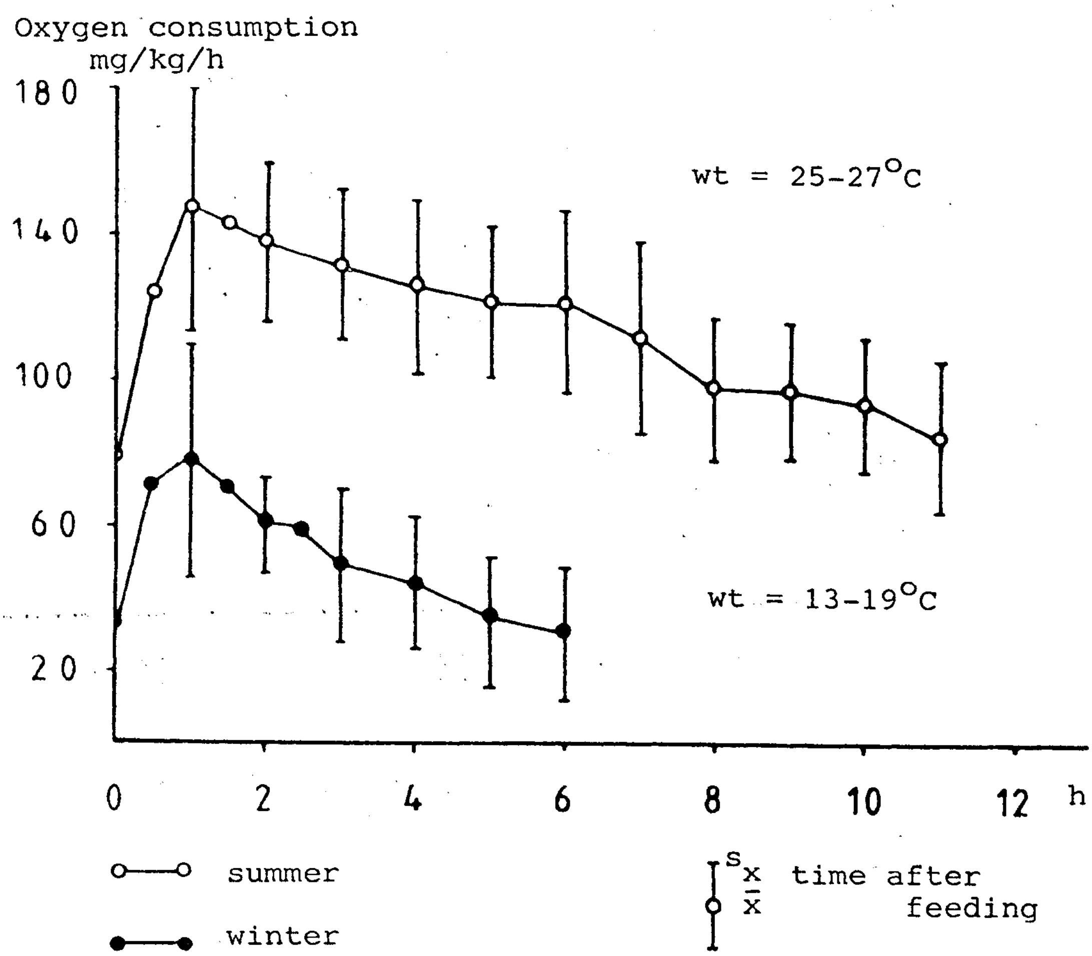


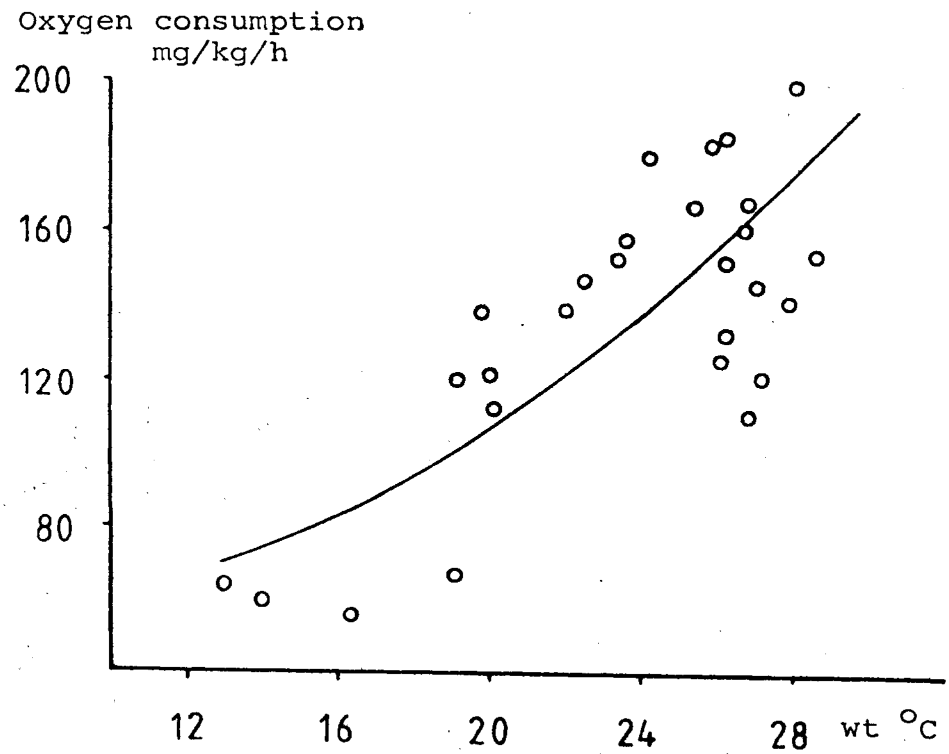
Fig. 2: Oxygen consumption of fed eels in summer and winter



feeding rate summer 1.6%

feeding rate winter 0.3-0.8%

Fig. 3: Maximum oxygen consumption of fed eels at various water temperatures



Regression: $y = 30.72 \cdot e^{0.063\,x}$

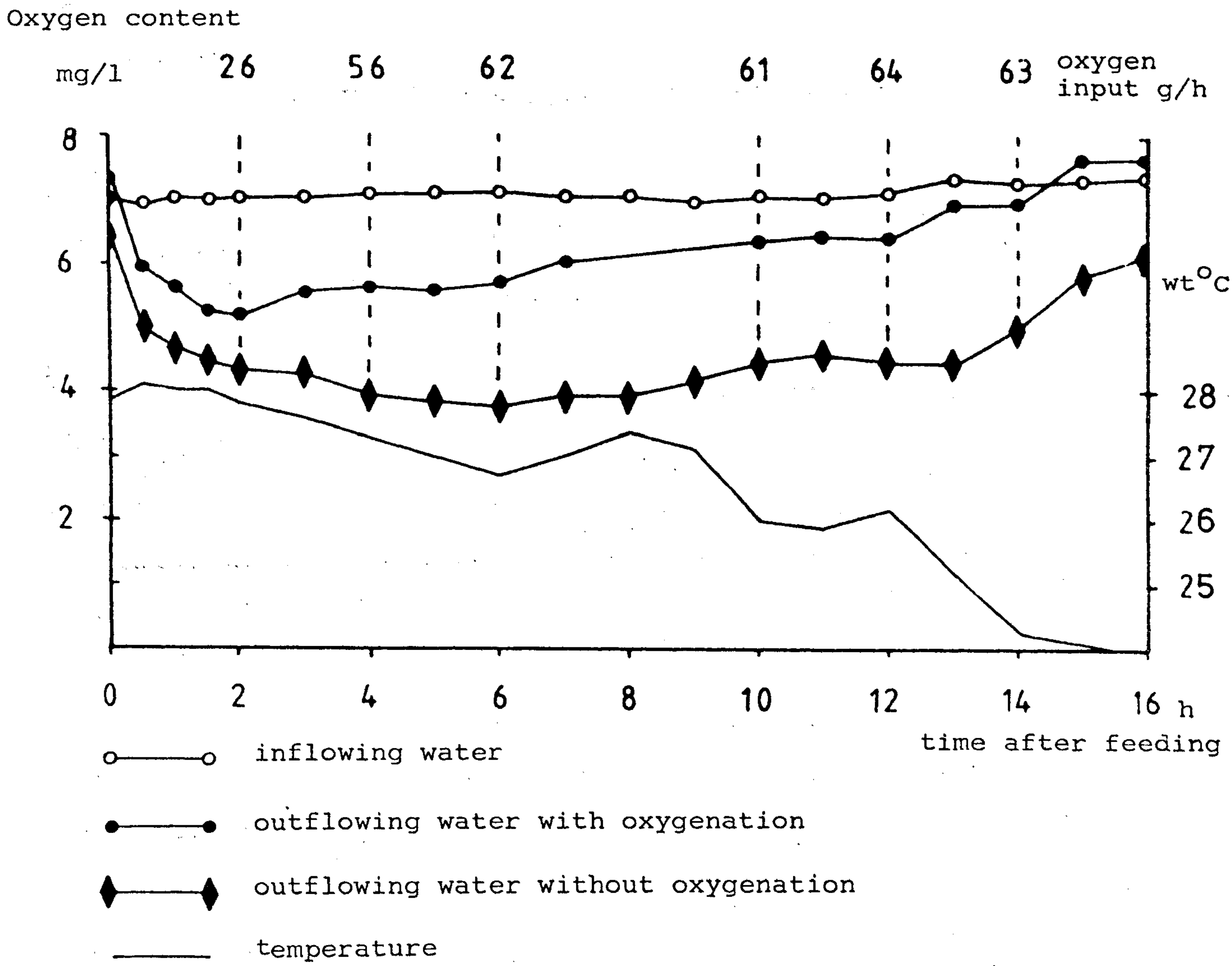
$r = 0.78$

$p = < 0.001$

y = oxygen consumption (mg/kg/h)

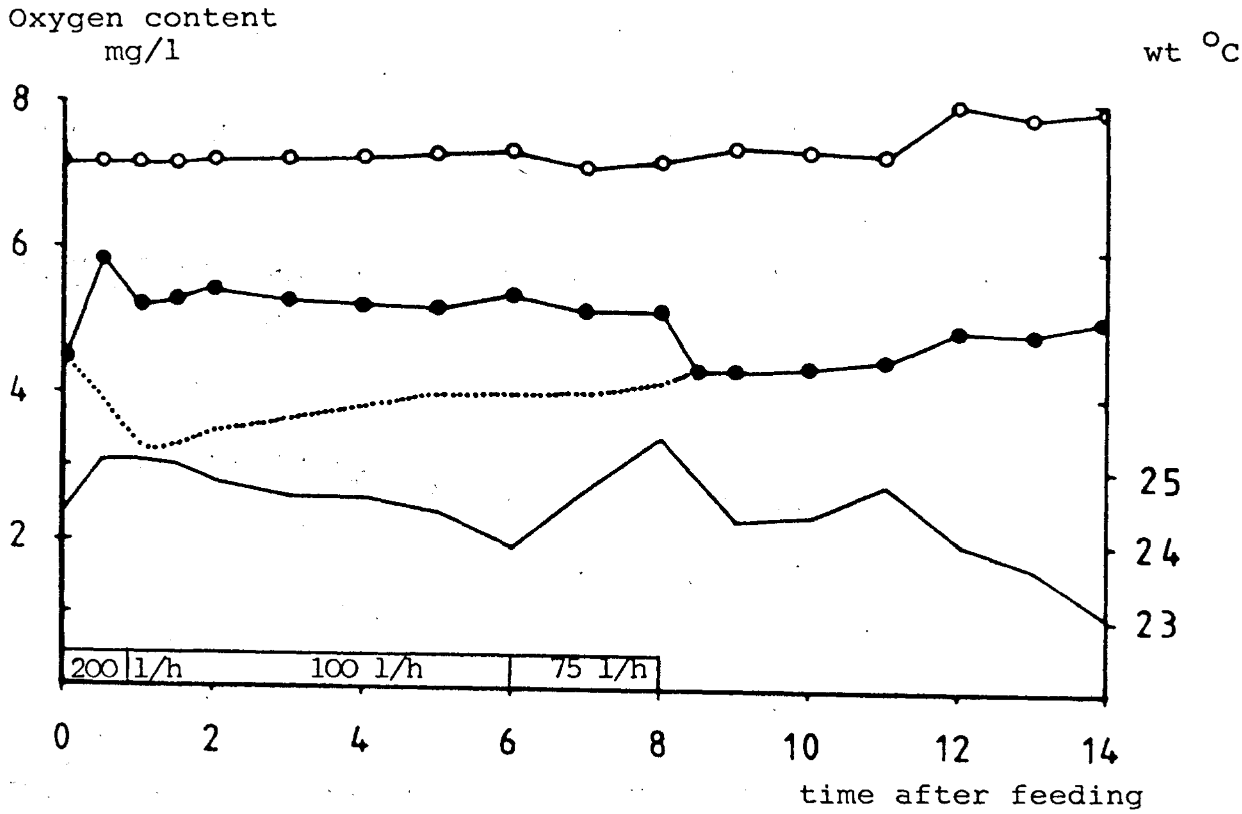
x = temperature (°C)

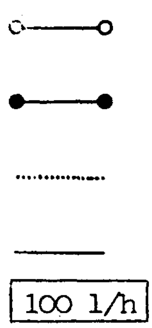
Fig. 4: Oxygen content of the inflowing and outflowing water with and without oxygenation after feeding by constant oxygenation intensity



Circular tank	: 8 cm Ø
Flow rate	: 9 l/s
Quantity of given food	: 6 kg (d.s.)
Weight of stock	: 550 kg
Remark	: water inlet under water surface

Fig. 5: Oxygen content of the inflowing and outflowing water with and without oxygenation after feeding by various oxygenating intensities





inflowing water

outflowing water

outflowing water without oxygenation calculated

temperature

time and intensity of oxygenation (gas input)

Circular tank	: 8 m Ø
Flow rate	: 8.6 l/s
Quantity of given food	: 12 kg (d.s.)
Weight of stock	: 732 kg